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(54) METHOD AND APPARATUS FOR CONTROLLING TORQUE OF A SERVO MOTOR.

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Description**Technical Field**

The present invention relates to a method and an apparatus for controlling the torque of a servomotor, in which a driving force applied actually to a load driven by the servomotor is controlled directly, and more particularly, to feedback control of a driving force applied to a load in pressure control, robot control, etc., in an injection-molding machine driven by a servomotor, and other systems of control of this type.

Background Art

In controlling a driving force applied to a load by using a servomotor, the output torque of the servomotor is conventionally controlled by torque restriction. An example of this is disclosed in EP-A-230470, which is relevant under Article 54(3) EPC. Since a motor output, however, is generally applied to the load through a transmission mechanism, the driving force applied actually to the load is controlled only indirectly, according to the prior art method of controlling the motor output. This entails the following awkward situations.

Fig. 2 is a block diagram of a basic circuit of a conventional control circuit for controlling a servomotor using a permanent-magnet synchronous motor. In Fig. 2, symbol E designates a three-phase power source. Reference numeral 3 denotes a rectifier circuit; 4, a transistor inverter; and 1, a transistor PWM control circuit. Also, symbol M designates the permanent-magnet synchronous motor, while numeral 2 denotes a rotor position detector, such as a pulse encoder, for detecting the position of a rotor of the permanent-magnet synchronous motor M.

The transistor PWM control circuit 1 compares a speed command value V_o from a control unit with a present speed V_s of the rotor, which is obtained from a rotor position S detected by the rotor position detector 2. Transistors TA to TF of the transistor inverter 4 are turned on or off to control currents flowing through the U-, V-, and W-phase windings of the permanent-magnet synchronous motor M, thereby controlling the rotating speed of the motor M. If the output torque of the motor M is to be controlled, the transistor PWM control circuit 1 is arranged as shown in Fig. 3.

In Fig. 3, numeral 5 denotes a signal processing circuit; 6 and 7, ROMs; and 8, a differential amplifier. The signal processing circuit 5 delivers a voltage V_s , indicative of the present rotor speed, in accordance with the rotor position detection output S. The ROMs 6 and 7 store a group of U- and W-phase command values to be delivered, so as to

correspond to individual rotor positions, in order to make the phase of the resultant current, flowing in the U, V, and W phases, perpendicular to that of the main flux of a magnetic field generated by the rotor. The differential amplifier 8 amplifies the difference between the voltage V_o , indicative of the speed command, and the voltage V_s , indicative of the present speed, from the signal processing circuit 5, and delivers an amplified difference signal. Numeral 9 denotes a filter which has a frequency characteristic such that the gain is lowered at high frequencies, and is increased at low frequencies. Zener diodes ZD1 of the filter 9 serve to clamp the peak voltage. Numerals 50 and 52 designate a D/A converter and a clamping circuit, respectively. The D/A converter 50 serves to convert a torque limiting command P_L , as a digital signal, into an analog signal. The command P_L , which is supplied from a numerical control unit (not shown) or the like, is used to set the value of the driving force to the load. If an input V_r to an amplifier 51, that is, a voltage V_r corresponding to the difference between the speed command V_o from the filter 9 and the present speed V_s , exceeds a predetermined voltage $+V_c$ or $-V_c$, which corresponds to a torque limiting command P_V , in the form of an analog signal, from the D/A converter 50, the clamping circuit 52 clamps the voltage V_r to the voltage $+V_c$ or $-V_c$. Numerals 10 and 11 denote multiplying digital-to-analog converters. The converter 10 multiplies a voltage V_E , delivered from the amplifier 51, by the U-phase command value delivered from the ROM 6. Likewise, the converter 11 multiplies the voltage V_E by the W-phase command value from the ROM 7. Thus, the converters 10 and 11 generate U- and W-phase current commands RTC and TTC, respectively. Numeral 12 denotes an adder for adding the U- and W-phase current commands RTC and TTC and generating a V-phase current command STC, which is shifted from the U and W phases by 120° . Numerals 13 and 14 denote detectors for detecting currents I_u and I_w flowing through the U- and W-phase armature windings of the synchronous motor M. Numeral 15 denotes an adder for adding U- and W-phase currents I_R and I_T , detected by the U- and W-phase current detectors 13 and 14, to calculate V-phase current I_S . Numerals 16, 17 and 18 denote circuits for delivering the current command voltages, which are indicative of the currents to be supplied to the U-, V-, and W-phase armature windings. The circuits 16, 17 and 18 are constructed in the same manner, provided that they are supplied with different input signals. The circuit 16 comprises an operational amplifier 19 for amplifying the difference between the U-phase current command RTC and the present U-phase detection current I_R , and a low-pass filter 20 for transmitting only the fre-

quency component of the reference carrier wave, as an output from the operational amplifier 19. The circuit 17 receives the V-phase current command STC and the present current IS, while the circuit 18 receives the W-phase current command TTC and the present current IT. As regards other arrangements, the circuits 17 and 18 are identical with the circuit 16. Numeral 21 denotes a circuit (hereinafter referred to as a PWM signal processing circuit) which is composed of a PWM signal processor and a transistor base drive amplifier. The PWM signal processing circuit 21 compares the signals from the circuits 16, 17 and 18 with the reference carrier wave VA, and generates PWM signals PA to PF for turning on and off the transistors TA to TF of the transistor inverter 4.

With the arrangement described above, the permanent-magnet synchronous motor M is controlled as follows. The difference between the speed command Vo and the present speed Vs, which is generated from the signal processing circuit 5 supplied with the rotor position signal S from the rotor position detector 2, is amplified by the differential amplifier 8, and is delivered as an output voltage Vr through the filter 9. If the voltage Vr is not higher than the clamping voltage +Vc or -Vc set by the clamping circuit 52, it is delivered directly, as an output VE, from the amplifier 51. If the voltage Vr is higher than the clamping voltage +Vc or -Vc, the clamping voltage is delivered as the output voltage VE (= +Vc or -Vc) of the amplifier 51, and is supplied to the multiplying digital-to-analog converters 10 and 11. After receiving an address signal, indicative of the present rotor position, from the signal processing circuit 5, the U- and W-phase ROMs 6 and 7 supply the multiplying digital-to-analog converters 10 and 11 with U- and W-phase command values corresponding to the present rotor position. The multiplying digital-to-analog converters 10 and 11 multiply the error signal VE by the command values from the ROMs 6 and 7, respectively, and generate U- and W-phase current commands RTC and TTC, respectively. The adder 12 adds the U- and W-phase current commands RTC and TTC, thereby delivering the V-phase current command STC. Operational amplifiers 19 in the circuits 16, 17 and 18 amplify the differences between the current commands RTC, STC, and TTC and the present U-, V-, and W-phase current values IR, IS, and IT detected by the U- and W-phase current detectors 13 and 14 and the adder 12. The amplified signals are filtered by the filters 20, and voltages corresponding to the individual phase command currents are delivered to the PWM signal processing circuit 21. The circuit 21 compares the voltages with the reference carrier wave VA, and delivers the PWM signals PA to PF to the transistor inverter 4 through

the transistor base drive amplifier. Thus, the transistors TA to TF of the transistor inverter are turned on and off to control the speed of the permanent-magnet synchronous motor M.

For example, an injection mechanism of an injection-molding machine may be driven by means of the permanent-magnet synchronous motor M, under the aforementioned speed control, so that resin is injected by means of a screw, and is subjected to pressure maintenance thereafter. In doing this, the pressure to be maintained has conventionally been controlled by controlling the output torque of the motor M, i.e., the driving current of the motor. In this case, if the torque limiting command PL, which is necessary for the pressure maintenance, is delivered from the numerical control unit or other control unit, the command PL is converted into an analog signal by the D/A converter 50, as mentioned before, and the clamping circuit 52 sets the clamping voltages +Vc and -Vc corresponding to the torque limiting command PL. When the injection ends, the screw of the injection mechanism ceases to move, and the motor M nearly stops from rotating, so that the difference between the voltage Vs, indicative of the present speed, and the voltage Vo for the speed command becomes large. As a result, the output voltage Vr from the filter 9 exceeds the set clamping voltage +Vc or -Vc, so that the amplifier 51 delivers the voltage VE corresponding to the set clamping voltage +Vc or -Vc to the multiplying digital-to-analog converters 10 and 11. Consequently, the U- and W-phase current commands RTC and TTC from the multiplying digital-to-analog converters 10 and 11 and the V-phase current command STC from the adder 12 take their respective values corresponding to the set clamping voltage +Vc or -Vc. Thus, the motor M delivers an output torque set in accordance with the torque limiting command PL. The output torque of the motor M can be varied by changing the value of the torque limiting command PL. In the pressure control for the injection-molding machine, therefore, the pressure to be maintained is varied in several steps by multistep setting of the torque limiting command PL.

However, the conventional control method, which is an open-loop method, is based only on the supposition that a driving force corresponding to torque restriction is applied to the load by effecting the torque restriction. More specifically, a torque delivered from the shaft of the servomotor is transmitted through a transmission mechanism or the like, to be supplied as a driving force to a load, e.g., a screw for injection and pressure maintenance. Due to various disturbances, such as friction on the transmission mechanism, etc., or deflection or the like of a spring or ball screw, the force applied actually to the load does not always agree

with the value set by torque restriction. In the injection-molding machine driven by the servomotor, if the pressure control is performed by torque restriction, as in the aforementioned case, a difference may often be produced between the set pressure to be applied to the resin and the pressure applied actually to the resin, due to friction on the transmission mechanism or the like.

According to one aspect of the present invention there is provided a torque control method for controlling the output torque of a servomotor by adjusting the driving current of the servomotor to a limited value or less by means of torque limiting means, comprising steps of detecting a driving force applied actually to a load, through a transmission mechanism, by the servomotor, comparing a detected value of the driving force with a set value of the driving force to be applied to the load, and driving the torque limiting means in accordance with the difference between the detected value and the set value, to control the driving current of the servomotor, thereby adjusting the driving force applied actually to the load to the set value in feedback control and compensating for any error in the driving force caused by disturbances in the transmission mechanism.

According to another aspect of the present invention there is provided a torque control apparatus for a servomotor, comprising:

signal processing circuit means adapted to receive a signal indicative of an actual rotational position of the servomotor, connected operatively to a load through a transmission mechanism, and to deliver an actual speed signal and a driving-current command signal corresponding to the actual rotational position;

comparator means for delivering, as an output, the difference between the actual speed signal and a speed command signal;

compensator means for compensating the driving-current command signal from the signal processing circuit means with the output from the comparator means;

feedback circuit means including clamping means for clamping the output from the comparator means to a predetermined value corresponding to the difference between a driving-force command signal, indicative of the driving force to be applied to the load, and a driving-force feedback signal, indicative of a driving force applied actually to the load; and

driver means for driving the servomotor in accordance with a detection driving current and the driving-current command signal compensated by the compensator means, thereby to compensate for any error in the driving force caused by disturbances in the transmission mechanism.

As described above, the driving force applied

actually to the load driven by the servomotor is detected, and is then feedback-controlled to a target value by the torque limiting means. In driving the load by means of the servomotor through the medium of the transmission mechanism, therefore, if the correlation between the output torque of the servomotor and the driving force applied to the load varies, due to friction on the transmission mechanism or deflection of the spring or ball screw, the torque limiting means is operated so that the driving force applied actually to the load is fed back and adjusted to the set point. Thus, the variation of the correlation can be compensated automatically, so that the driving force can be adjusted accurately to the set point.

Brief Description of the Drawings

- Fig. 1 is a block diagram showing a transistor WM control circuit according to an embodiment of the present invention;
 Fig. 2 is a basic circuit diagram of a control circuit of a servomotor including the transistor PWM control circuit of Fig. 1;
 Fig. 3 is a block diagram of a transistor PWM control circuit for a conventional method of torque restriction;
 Fig. 4 is a block diagram of a pressure-control feedback circuit; and
 Fig. 5 is a diagram for illustrating the pressure-control feedback circuit.

Best Mode of Carrying Out the Invention

Fig. 1 shows a transistor PWM control circuit 1' according to an embodiment of the present invention, which is used as the transistor PWM control circuit 1 in the basic circuit diagram shown in Fig. 2. The control circuit 1' of Fig. 1 differs from the conventional transistor PWM control circuit 1 for torque restriction, shown in Fig. 3, in that it uses a pressure-controlled feedback circuit 53 in place of the clamping circuit 52 of Fig. 3. Fig. 4 is a block diagram of the pressure-controlled feedback circuit 53, and Fig. 5 is a detailed circuit diagram thereof.

In Figs. 1, 4 and 5, symbol PST designates a switching command signal, which is used to determine whether or not the driving force applied actually to the load by the motor M is to be controlled by a feedback control loop (mentioned later). In response to the signal PST, an analog switch ASW is shifted. Symbol PV designates a driving force command voltage (≤ 0) which is obtained by converting a driving force command PL' into an analog signal by means of the D/A converter 50 shown in Fig. 1. The command PL', which is supplied from a control unit, corresponds to the driving force to be applied to the load. Symbol PH designates a de-

tection load pressure voltage which is indicative of the driving force or pressure applied actually to the load. The voltage PH is supplied from a pressure detector (not shown) or the like which is attached to the load.

In Fig. 4, numeral 54 denotes a comparator circuit, which compares the driving force command voltage PV from the D/A converter 50 with the feedback signal from the pressure detector, and delivers an output indicative of the difference between the voltage PV and the signal PH. Numeral 55 denotes an amplifier-compensator circuit, which receives the output from the comparator circuit 54 through a volume control RV1 for determining the gain of pressure feedback. The amplifier-compensator circuit 55 amplifies the output from the comparator circuit 54, and delivers its output. Symbol ASW designates the analog switch, which is shifted in response to the switching command signal PST for the determination on the feedback control of the force applied to the load. Numeral 56 denotes a bipolar clamping circuit, which delivers the clamping voltage +Vc or -Vc to the amplifier 51 (see Fig. 1), in response to a voltage applied to the circuit 56, and clamps the output Vr from the filter 9 to the clamping voltage +Vc or -Vc. Symbol RV2 designates a volume control for compensating the detection signal from the pressure detector.

The operation of the aforementioned control circuit will now be described in connection with a case such that an injection mechanism of an injection-molding machine, for example, is driven by means of the motor M for pressure control.

During injection, the torque restriction is not executed, that is, the driving force command PL' from the control unit is set to its maximum, and a maximum voltage (e.g., -10 V) is delivered from the output PV of the D/A converter 50. Since no pressure feedback is performed, the switching command signal PST is not generated, so that the analog switch ASW is in the state shown in Fig. 4. In this state, the driving force command voltage PV is applied directly to the clamping circuit 53, and the maximum voltage +Vc or -Vc is delivered from the clamping circuit 53. In consequence, as mentioned before, the difference between the speed command voltage Vo and the voltage Vs, indicative of the present speed, is delivered through the differential amplifier 8 and the filter 9. The voltage Vr is supplied to the multiplying digital-to-analog converters 10 and 11 through the amplifier 51, without being limited by the clamping circuit 56. Thus, the motor M is driven only under speed control, without torque restriction, to accomplish injection control.

Subsequently, when a step of pressure maintenance is reached after the end of the injection process, the switching command signal PST is

delivered, so that the analog switch ASW is shifted so that switches SW1 and SW2 are turned off and on, respectively. Meanwhile, the driving force command (hereinafter referred to as the pressure maintenance command) PL' corresponding to a first step of pressure maintenance is delivered from the control unit, and the voltage PV corresponding to the command PL' is supplied from the D/A converter 50 to the comparator circuit 54. The comparator circuit 54 compares the voltage PV with the load pressure voltage PH (≥ 0), as a detection signal, from the pressure detector (not shown) or the like which is provided in a die. The difference between the voltages PV and PH is delivered to the amplifier-compensator circuit 55 via the volume control RV1. Then, the output of the amplifier-compensator circuit 55 is applied to the clamping circuit 56 through the switch SW2 of the analog switch ASW. Thereupon, the clamping circuit 56 delivers the clamping voltage +Vc or -Vc in accordance with the difference between the pressure maintenance command voltage PV and the load pressure voltage PH from the pressure detector.

During the pressure maintenance, a screw of the injection mechanism (not shown) is substantially stopped from moving, and the motor M is also stopped. However, the speed command Vo keeps on being generated, so that the voltage Vr delivered from the filter 9 is determined by the set point of the Zener diodes ZD1. Thus, the filter 9 delivers the voltage Vr which causes the motor M to produce its maximum driving force. Accordingly, the input of the amplifier 51 is clamped at the clamping voltage +Vc or -Vc of the clamping circuit 56, so that the voltage VE corresponding to the clamping voltage +Vc or -Vc is delivered to the multiplying digital-to-analog converters 10 and 11. Thus, the output torque of the motor M can be controlled in accordance with the clamping voltage +Vc or -Vc, or the value of the maintenance command PL'.

If the difference between the voltage PV, corresponding to the pressure maintenance command PL', and the load pressure voltage PH from the pressure detector is large, the output of the amplifier-compensator circuit 55 is large, so that the voltage applied to the clamping circuit 56 is high. Accordingly, the clamping voltage +Vc or -Vc increases, so that the phase current commands RTC, TTC, and STC, delivered from the multiplying digital-to-analog converters 10 and 11 and the adder 12, respectively, are augmented, and the output torque of the motor M increases. If the load pressure PH, as the detection signal from the pressure detector, increases so that its difference from the command voltage PV becomes smaller, the output of the amplifier-compensator circuit 55 is lowered. Accordingly, the output +Vc or -Vc of the

clamping circuit 56 is also lowered, and the output torque of the motor M is reduced. As a result, the difference between the command voltage PV and the load pressure voltage PH from the pressure detector is settled at a fixed value. This indicates that the pressure of the resin in the die, as the load, is stabilized when it reaches the pressure maintenance delivered from the control unit, that is, the target pressure for pressure maintenance. Thus, if the torque is absorbed from the motor M by friction on the transmission system or deflection of the spring or ball screw, the pressure inside the die is compared directly with the command pressure for pressure maintenance, and feedback control is performed so that the internal pressure of the die is adjusted to the set pressure. Accordingly, there will be caused no such errors as conventional ones. In the pressure maintenance, which is performed in several steps, the pressure to be maintained can be changed automatically to the set pressure in each pressure maintenance step by changing the pressure maintenance command PL' and hence the command voltage PV.

Fig. 5 is a specific circuit diagram of the pressure-controlled feedback circuit 53, in which the comparator circuit 54 is composed of an operational amplifier IC3, and the amplifier-compensator circuit 55 includes an operational amplifier IC4, a Zener diode ZD2 for clamping the output to a fixed voltage, and a capacitor C1 and resistors R1 to R3 for stabilizing pressure feedback. The analog switch ASW includes three switches SW1 to SW3. Symbol I designates an inverter. The switches SW1 and SW3 are turned on and off synchronously in association with each other. The switch SW2 is turned on and off oppositely to the switches SW1 and SW3. More specifically, when the switching command PST is at low level (TTL logic level), the switches SW1 and SW3 are on, and the switch SW2 is off. If the level of the command PST goes high, the switches SW1 and SW3 are turned off, and the switch SW2 is turned on. The clamping circuit 56 is composed of two operational amplifiers IC1 and IC2, diodes D1 and D2, etc. The operational amplifiers IC1 and IC2 constitute an amplifier and a code converter, respectively. A negative voltage applied to the operational amplifier IC1 (pressure maintenance command voltage PV and the output voltage of the amplifier-compensator circuit 55 are negative voltages) is amplified and delivered as a positive voltage by the operational amplifier IC1. This output voltage serves as the positive clamping voltage +Vc. The operational amplifier IC2, for use as the code converter, converts the voltage +Vc into a negative voltage -Vc, thus generating the negative clamping voltage -Vc. When the output Vr (see Fig. 1) of the filter 9 reaches the level of the positive clamping voltage

+Vc or a higher level, the diode D1 starts to conduct, and the input of the amplifier 51 is kept below the level of the clamping voltage +Vc. When the output Vr of the filter 9 is lowered to the level of the negative clamping voltage -Vc or a lower level, on the other hand, the diode D2 starts to conduct, and the input of the amplifier 51 is kept above the level of the negative clamping voltage -Vc.

Resistors R4 and R5 and a capacitor C2 constitute an integration circuit, which serves to lessen the change of the voltage PV (step voltage). The switch SW3 of the analog switch ASW is adapted to short the capacitor C1 to discharge the same when it is turned on.

The operation of the aforementioned circuit will now be described. When the pressure feedback control is off, the switching signal PST is at low level. In this state, the switches SW1 and SW3 of the analog switch ASW are on, and the switch SW2 is off, as shown in Fig. 5. Thus, the pressure maintenance command voltage PV is applied to the clamping circuit 56. In starting the pressure feedback control or pressure control, on the other hand, the switching signal PST is shifted to high level, the switch SW2 is turned on, and the switches SW1 and SW3 are turned off. When the pressure maintenance command voltage PV (< 0) is applied to the operational amplifier IC3 of the comparator 54, it is compared with the voltage PH (> 0) which is delivered from the pressure detector and corrected by means of the volume control RV2. The difference between the voltages PV and PH is delivered from the comparator 54, and is supplied to the operational amplifier IC4 via the volume control RV1 which is used to determine the amplification degree. Immediately after the start of the pressure feedback control, the detected pressure from the pressure detector is unstable. In a transient state such that the pressure maintenance command voltage PV changes, moreover, the capacitor C1 is shorted for a short period of time, so that the gain of the operational amplifier IC4 serves as an inverted amplifier having a low gain determined by -R2/R1. When the capacitor C1 finishes being charged, the gain of the operational amplifier IC4 reaches a high level of -(R2 + R3)/R1. Thus, in a transient state such that the voltage applied to the operational amplifier IC4 varies, the gain is lowered. As the voltage becomes stable, the gain is increased, and the clamping voltage +Vc or -Vc is changed gradually, thereby improving the stability of the pressure feedback control.

In the embodiment described above, the torque control method of the present invention is applied to the pressure control in an injection-molding machine which uses a servomotor as the drive source of its injection mechanism. However, the present

invention may be applied also to various other systems of control than the pressure control for such an injection-molding machine. According to such alternative control systems, a force applied actually to a load can be detected for the control of the force on the load.

In the above embodiment, moreover, an AC servomotor using a synchronous motor is described as being subjected to torque control. The present invention may, however, be applied also to the torque control of a DC servomotor.

Claims

1. A torque control method for controlling the output torque of a servomotor (M) by adjusting the driving current of the servomotor (M) to a limited value or less by means of torque limiting means (53), comprising steps of detecting a driving force applied actually to a load, through a transmission mechanism, by the servomotor (M), comparing a detected value (PH) of the driving force with a set value (PV) of the driving force to be applied to the load, and driving the torque limiting means (53) in accordance with the difference between the detected value (PH) and the set value (PV), to control the driving current of the servomotor (M), thereby adjusting the driving force applied actually to the load to the set value (PV) in feedback control and compensating for any error in the driving force caused by disturbances in the transmission mechanism. 15
2. A torque control method for a servomotor according to claim 1, wherein a gain on said feedback control is lowered while the difference between the detected value (PH) and the set value (PV) of said driving force is varying, and is increased when said difference is stable, thereby stabilizing the feedback control. 20
3. A torque control method for a servomotor according to claim 1 or 2, wherein said servomotor (M) is used as a drive source for an injection mechanism of an injection-molding machine, and a pressure applied to resin is detected for pressure maintenance, so that the torque limiting means (53) is driven in accordance with the difference between the detected pressure and a set pressure as a target value, thereby effecting pressure maintenance control. 25
4. A torque control apparatus for a servomotor, comprising:
signal processing circuit means (5) adapted to receive a signal (S) indicative of an 30
5. A torque control apparatus for a servomotor according to claim 4, wherein said feedback circuit means (53) includes second comparator means (54) for comparing said driving-force command signal (PV) and said driving-force feedback signal (PH) and delivering an output corresponding to the result of said comparison, and amplifier-compensator means (55) for amplifying the output from said second comparator means (55) and supplying the amplified output to said clamping means (56). 35
6. A torque control apparatus for a servomotor according to claim 5, wherein said feedback circuit means (53) includes changeover switch means (ASW) for alternatively connecting said clamping means (56) to the input side of said comparator circuit (54) or the output side of said amplifier-compensator means (55). 40
7. A torque control apparatus for a servomotor according to claim 5 or 6, wherein said amplifier-compensator means (55) of said feedback circuit means (53) includes an operational amplifier (IC4), a plurality of resistors (R1,R2,R3) for determining the gain of said operational amplifier (IC4), and a capacitor 45

actual rotational position of the servomotor (M), connected operatively to a load through a transmission mechanism, and to deliver an actual speed signal (Vs) and a driving-current command signal corresponding to the actual rotational position;

comparator means (8) for delivering, as an output, the difference between the actual speed signal (Vs) and a speed command signal (V0);

compensator means for compensating the driving-current command signal from the signal processing circuit means (5) with the output from the comparator means (8);

feedback circuit means (53) including clamping means (56) for clamping the output from the comparator means (8) to a predetermined value corresponding to the difference between a driving-force command signal (PV), indicative of the driving force to be applied to the load, and a driving-force feedback signal (PH), indicative of a driving force applied actually to the load; and

driver means for driving the servomotor (M) in accordance with a detection driving current and the driving-current command signal compensated by the compensator means, thereby to compensate for any error in the driving force caused by disturbances in the transmission mechanism.

5. A torque control apparatus for a servomotor according to claim 4, wherein said feedback circuit means (53) includes second comparator means (54) for comparing said driving-force command signal (PV) and said driving-force feedback signal (PH) and delivering an output corresponding to the result of said comparison, and amplifier-compensator means (55) for amplifying the output from said second comparator means (55) and supplying the amplified output to said clamping means (56).

6. A torque control apparatus for a servomotor according to claim 5, wherein said feedback circuit means (53) includes changeover switch means (ASW) for alternatively connecting said clamping means (56) to the input side of said comparator circuit (54) or the output side of said amplifier-compensator means (55). 50

7. A torque control apparatus for a servomotor according to claim 5 or 6, wherein said amplifier-compensator means (55) of said feedback circuit means (53) includes an operational amplifier (IC4), a plurality of resistors (R1,R2,R3) for determining the gain of said operational amplifier (IC4), and a capacitor 55

- (C1) adapted to be charged to cause a short across at least one of said resistors (R3), in a transient state such that said driving force command signal changes, thereby reducing the gain of said operational amplifier (IC4).
- Patentansprüche**
1. Drehmomentsteuerungsverfahren zur Steuerung des Abtriebsdrehmoments eines Servomotors (M) durch Einstellung des Antriebsstroms des Servomotors (M) auf einen Grenzwert oder darunter mittels eines Drehmomentbegrenzungsmittels (53), bestehend aus den Schritten
 - Ermittlung einer tatsächlich von dem Servomotor (M) über einen Übertragungsmechanismus auf eine Last übertragenen Antriebskraft,
 - Vergleich eines ermittelten Werts (PH) der Antriebskraft mit einem Sollwert (PV) der Antriebskraft, die auf die Last übertragen werden soll, und
 - Antrieb des Drehmomentbegrenzungsmittels (53) gemäß der Differenz zwischen dem ermittelten Wert (PH) und dem Sollwert (PV), um den Antriebsstrom des Servomotors (M) zu steuern, wodurch die tatsächlich auf die Last übertragene Antriebskraft durch Rückkopplungs-Steuerung auf den Sollwert (PV) eingestellt und jede durch Störungen im Übertragungsmechanismus verursachte Abweichung der Antriebskraft ausgeglichen wird.
 2. Drehmomentsteuerungsverfahren für einen Servomotor nach Anspruch 1, wobei der Verstärkfaktor der Rückkopplungs-Steuerung verringert wird, während sich die Differenz zwischen dem ermittelten Wert (PH) und dem Sollwert (PV) der genannten Antriebskraft ändert, und vergrößert wird, wenn die genannte Differenz gleichbleibend ist, wodurch die Rückkopplungs-Steuerung stabilisiert wird.
 3. Drehmomentsteuerungsverfahren für einen Servomotor nach Anspruch 1 oder 2, wobei der genannte Servomotor (M) als Antriebsquelle für einen Einspritzmechanismus einer Spritzgußmaschine verwendet wird und ein auf einen Kunststoff ausgeübter Druck zur Druckhaltung ermittelt wird, so daß das Drehmomentbegrenzungsmittel (53) gemäß der Differenz zwischen dem ermittelten Druck und dem eingestellten Druck, dem Zielwert, angetrieben wird, wodurch eine Druckhaltungssteuerung bewirkt wird.
 4. Drehmomentsteuerungsvorrichtung für einen Servomotor, bestehend aus:
 - einem Signalverarbeitungsschaltungsmittel (5), das geeignet ist, ein Signal (S) zu empfangen, das die aktuelle Drehposition des Servomotors (M) anzeigt, der über einen Übertragungsmechanismus treibend mit einer Last verbunden ist, sowie ein Ist-Geschwindigkeit-Signal (Vs) und ein Antriebsstrom-Befehlssignal entsprechend der aktuellen Drehposition abzugeben;
 - einem Vergleichermittel (8) zur Ausgabe der Differenz zwischen dem Ist-Geschwindigkeit-Signal (Vs) und einem Geschwindigkeits-Befehlssignal (V0);
 - einem Kompensatormittel zur Kompensation des von dem Signalverarbeitungsschaltungsmittel (5) abgegebenen Antriebsstrom-Befehlssignals mit der Ausgabe des Vergleichermittels (8);
 - einem Rückkopplungsschaltungsmittel (53) mit einem Klemmmittel (56) zum Klemmen der Ausgabe des Vergleichermittels (8) auf einen vorher bestimmten Wert, der der Differenz zwischen einem Antriebskraft-Befehlssignal (PV), das die auf die Last zu übertragende Antriebskraft anzeigt, und einem Antriebskraft-Rückkopplungssignal (PH), das die tatsächlich auf die Last übertragene Antriebskraft anzeigt, entspricht;
 - Antriebsmitteln zum Antrieb des Servomotors (M) gemäß einem Ermittlungs-Antriebsstrom und dem von den Kompensatormitteln kompensierten Antriebsstrom-Befehlssignal, wodurch jede durch Störungen im Übertragungsmechanismus verursachte Abweichung der Antriebskraft ausgeglichen wird.
 - Drehmomentsteuerungsvorrichtung für einen Servomotor nach Anspruch 4, wobei das genannte Rückkopplungsschaltungsmittel (53) ein zweites Vergleichermittel (54) zum Vergleichen des genannten Antriebskraft-Befehlssignals (PV) und des genannten Antriebskraft-Rückkopplungssignals (PH) und zur Lieferung einer dem Ergebnis des genannten Vergleichs entsprechenden Ausgabe einschließt, sowie ein Verstärker-Kompensator-Mittel (55) zum Verstärken der Ausgabe des genannten zweiten Vergleichermittels (54) und zum Weiterleiten der verstärkten Ausgabe an das genannte Klemmmittel (56).
 - Drehmomentsteuerungsvorrichtung für einen

- Servomotor nach Anspruch 5, wobei das genannte Rückkopplungsschaltungsmittel (53) ein Umschaltermittel (ASW) einschließt, um das genannte Klemmmittel (56) entweder mit der Eingangsseite des genannten Vergleichermittels (54) oder der Ausgangsseite des genannten Verstärker-Kompensator-Mittels (55) zu verbinden.
7. Drehmomentsteuerungsvorrichtung für einen Servomotor nach Anspruch 5 oder 6, wobei das genannte Verstärker-Kompensator-Mittel (55) des genannten Rückkopplungsschaltungsmittels (53) einen Operationsverstärker (IC4), eine Vielzahl von Widerständen (R1, R2, R3) zur Festlegung der Verstärkung des genannten Operationsverstärkers (IC4) sowie einen Kondensator (C1) einschließt, der dafür geeignet ist, so aufgeladen zu werden, daß er in einem Übergangszustand, in dem sich das genannte Antriebskraft-Befehlssignal ändert, über mindestens einen der genannten Widerstände (R3) einen Kurzschluß bewirkt, wodurch die Verstärkung des genannten Operationsverstärkers (IC4) verringert wird.
- Revendications**
1. Un procédé de régulation de couple pour commander le couple de sortie d'un servo-moteur (M), en réglant le courant d'entraînement du servo-moteur (M) à une valeur limite ou inférieure par l'intermédiaire d'un moyen de limitation de couple (53), comprenant les opérations consistant à détecter une force d'entraînement appliquée réellement à une charge, à travers un mécanisme de transmission, par le servo-moteur (M), à comparer une valeur détectée (PH) de la force d'entraînement avec une valeur de consigne (PV) de la force d'entraînement à appliquer à la charge, à entraîner le moyen de limitation de couple (53) en accord avec la différence entre la valeur détectée (PH) et la valeur de consigne (PV), afin de commander le courant d'entraînement du servo-moteur (M), en réglant ainsi la force d'entraînement, appliquée réellement à la charge, à la valeur de consigne (PV) dans une commande en contre-réaction, et à compenser pour toute erreur dans la force d'entraînement provoquée par des perturbations dans le mécanisme de transmission.
 2. Un procédé de régulation de couple pour un servo-moteur selon la revendication 1, dans lequel le gain de ladite commande en contre-réaction est abaissé pendant que la différence entre la valeur détectée (PH) et la valeur de consigne (PV) de ladite force d'entraînement est en cours de variation, et est augmenté lorsque ladite différence est stable, en stabilisant ainsi la commande en contre-réaction.
 3. Un procédé de régulation de couple pour un servo-moteur selon la revendication 1 ou 2, dans lequel ledit servo-moteur (M) est utilisé en tant que source d'entraînement pour un mécanisme d'injection d'une machine de moulage par injection, et une pression appliquée à la résine est détectée en vue de maintenir la pression, de sorte que le moyen de limitation de couple (53) est entraîné en accord avec la différence entre la pression détectée et une pression de consigne considérée comme valeur cible, en effectuant ainsi une commande de maintien.
 4. Un appareil de commande de couple pour un servo-moteur comprenant :
 - un moyen formant circuit de traitement de signaux (5) prévu pour recevoir un signal (S) représentatif d'une position réelle de rotation du servo-moteur (M), relié de manière fonctionnelle à une charge à travers un mécanisme de transmission, et pour fournir un signal de vitesse réelle (Vs) et un signal d'ordre de courant d'entraînement correspondant à la position réelle de rotation ;
 - un moyen formant comparateur (8) pour fournir, en sortie, la différence entre le signal de vitesse réelle (Vs) et un signal d'ordre de vitesse (Vo) ;
 - un moyen formant compensateur pour compenser le signal d'ordre de courant d'entraînement provenant du moyen formant circuit de traitement de signaux (5) avec la sortie du moyen formant comparateur (8) ;
 - un moyen formant circuit de contre-réaction (53) comprenant un moyen de blocage (56) pour bloquer la sortie du moyen formant comparateur (8) à une valeur prédéterminée correspondant à la différence entre un signal d'ordre de force d'entraînement (PV), représentatif de la force d'entraînement à appliquer à la charge, et un signal de contre-réaction de force d'entraînement (PH), représentatif d'une force d'entraînement appliquée réellement à la charge ; et
 - un moyen d'entraînement pour entraîner le servo-moteur (M) en accord avec un courant d'entraînement de détection et le signal de

- commande de courant d'entraînement compensé par le moyen formant compensateur, de manière ainsi à compenser pour toute erreur dans la force d'entraînement provoquée par des perturbations dans le mécanisme de transmission.
- 5.
- Un appareil de commande de couple pour un servo-moteur selon la revendication 4, dans lequel ledit moyen formant circuit de contre-réaction (53) comprend un second moyen formant comparateur (54) pour comparer ledit signal d'ordre de force d'entraînement (PV) et ledit signal de contre-réaction de force d'entraînement (PH) et fournir une sortie correspondant au résultat de ladite comparaison, et un moyen formant amplificateur-compensateur (55) pour amplifier la sortie dudit second moyen formant comparateur (55) et fournir, audit moyen de blocage (56), la sortie amplifiée.
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- 6.
- Un appareil de commande de couple pour un servo-moteur selon la revendication 5, dans lequel ledit moyen formant circuit de contre-réaction (53) comprend un moyen formant commutateur de changement (ASW) pour relier alternativement ledit moyen de limitation (56) au côté d'entrée dudit moyen formant comparateur (54) ou au côté de sortie dudit moyen formant amplificateur-compensateur (55).
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- 7.
- Un appareil de commande de couple pour un servo-moteur selon la revendication 5 ou 6, dans lequel ledit moyen formant amplificateur-compensateur (55) dudit moyen formant circuit de contre-réaction (53) comprend un amplificateur opérationnel (IC4), un ensemble de résistances (R1, R2, R3) pour déterminer le gain dudit amplificateur opérationnel (IC4), et un condensateur (C1) prévu pour être chargé afin de provoquer un court-circuit aux bornes d'au moins une desdites résistances (R3), dans un état transitoire tel que ledit signal d'ordre de force d'entraînement change, en réduisant ainsi le gain dudit amplificateur opérationnel (IC4).
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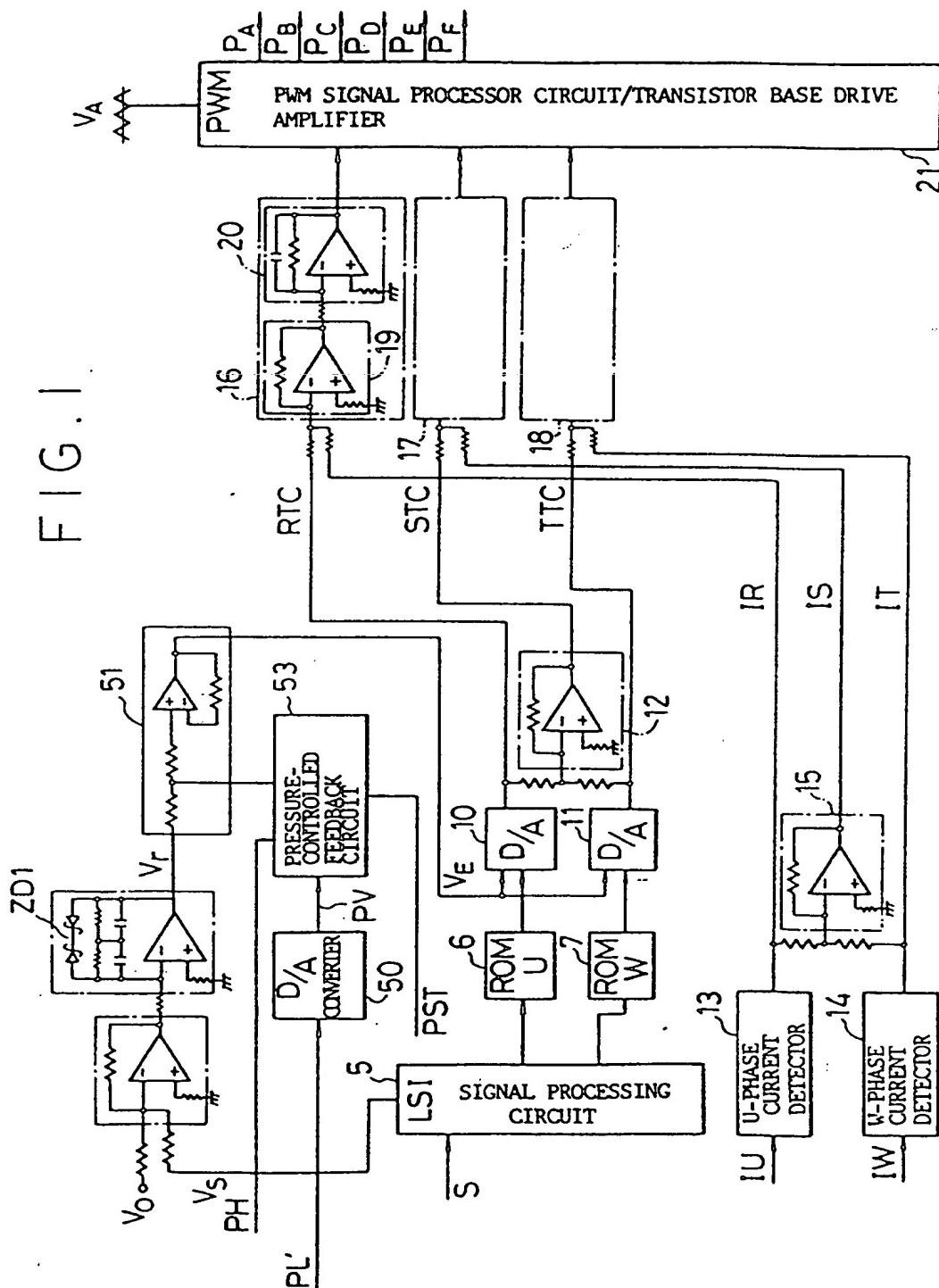


FIG. 2

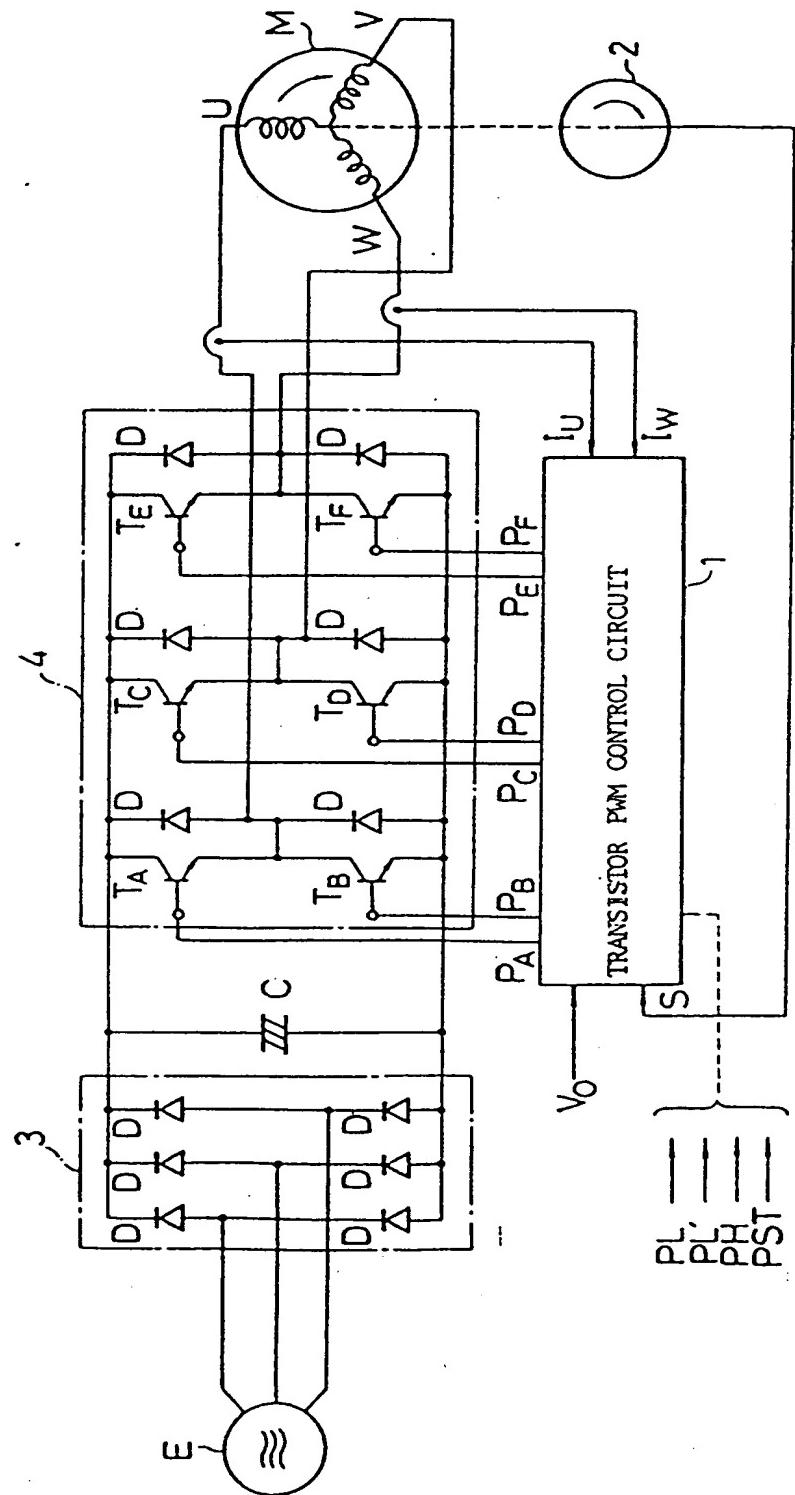


FIG. 3

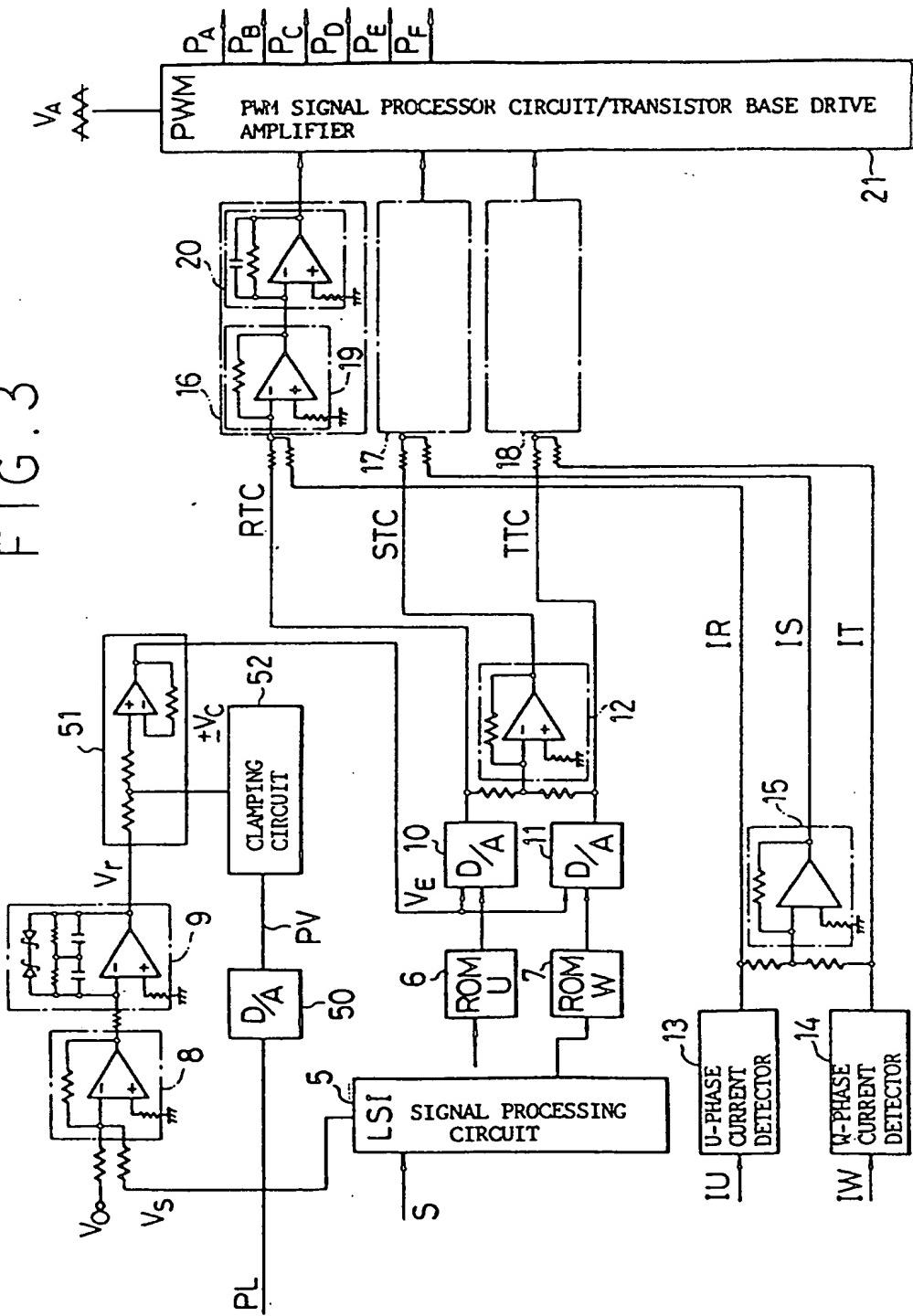


FIG. 4

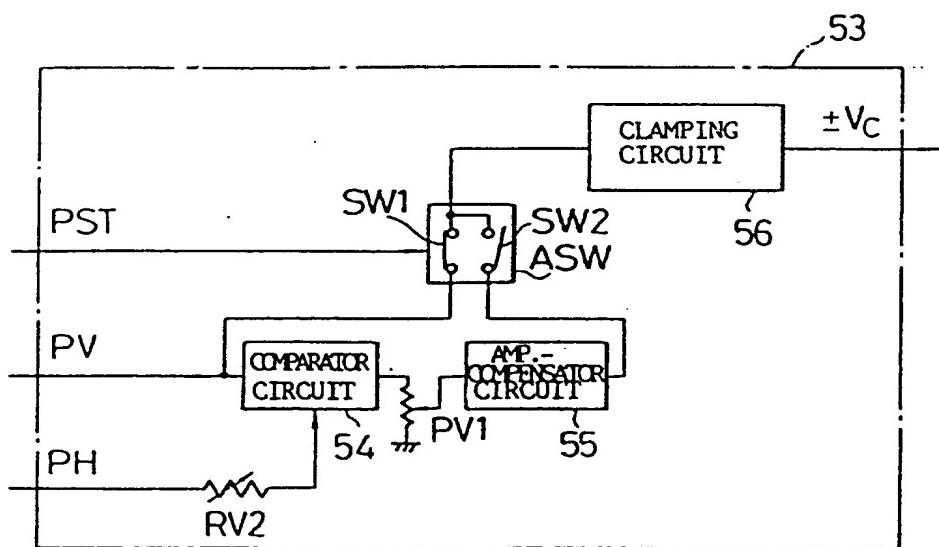
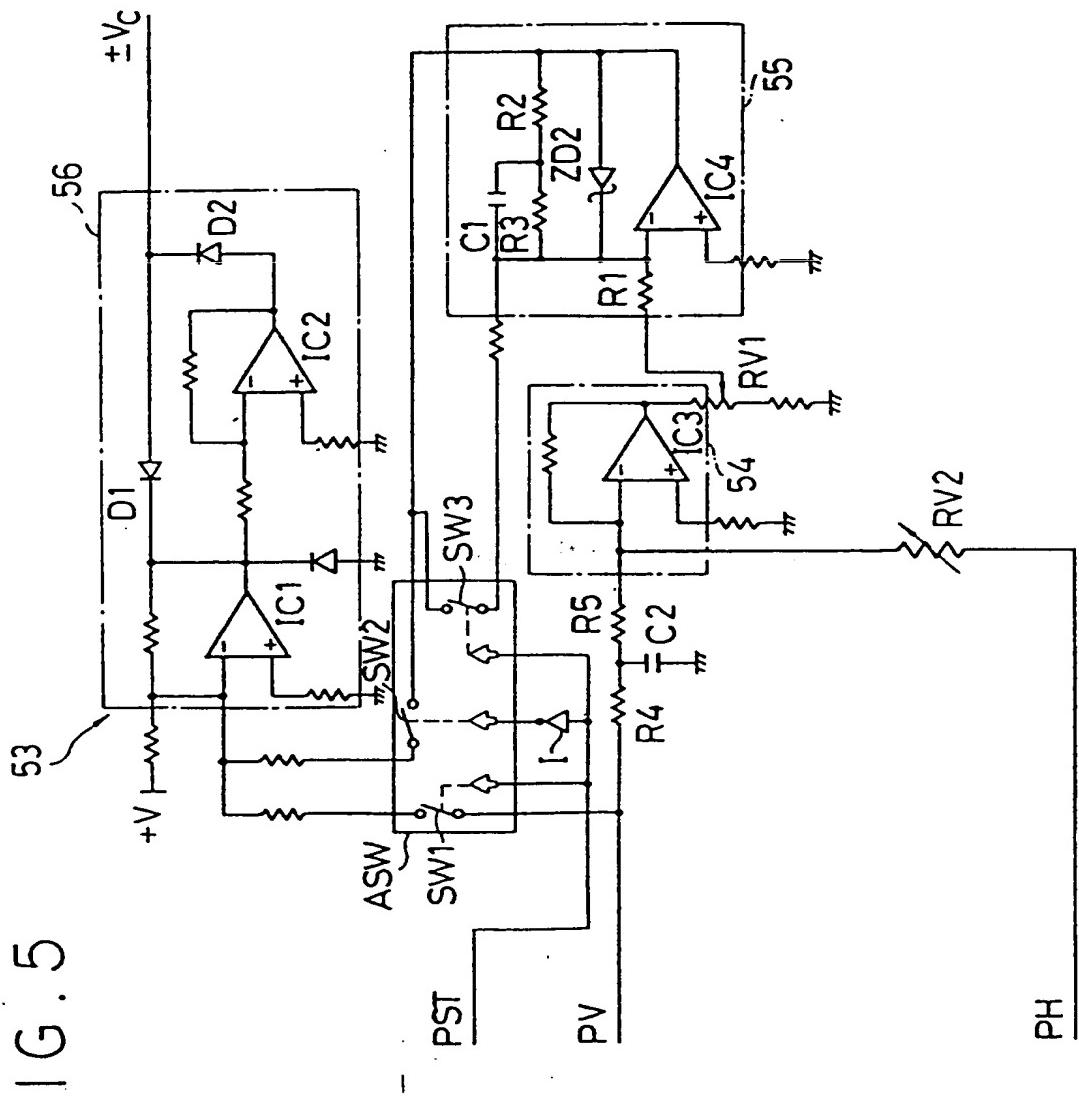
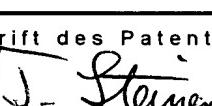


FIG. 5



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NR.	Dokument	Bemerkungen
	<input type="checkbox"/> aus Recherchenbericht	
	<input checked="" type="checkbox"/> in der Beschreibungseinleitung genannt	
1.	EP 0 246 326 B1	
	<input type="checkbox"/> weiterer Stand der Technik	
	<input type="checkbox"/> im engen Zusammenhang stehende US-Anmeldungen	
Unterschrift des Patentingenieurs Steiner 		Datum 28.05.2001

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